

1 Attorney Docket No. 80116

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3 ACOUSTIC REMOTE CAVIATION AS A DESTRUCTION DEVICE

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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and  
7 used by or for the Government of the United States of America  
8 for governmental purposes without the payment of any royalties  
9 thereon or therefor.

10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 This invention generally relates to an environmentally  
14 clean device to eliminate or destroy unwanted underwater  
15 objects remotely without using explosive materials. More  
16 particularly, the invention uses a general-purpose active  
17 sonar array to remotely eliminate or destroy unwanted  
18 underwater objects.

19 (2) Description of the Prior Art

20 The current art for the underwater destruction of  
21 unwanted objects is as varied as the devices to be destroyed.

22 The following patents, for example, disclose a generating  
23 a cavitation area at a very close range and/or within an  
24 enclosed space and at high frequencies, but do not disclose  
25 generating a cavitation in an essentially free water space and  
26 at relatively low frequencies in order to destroy a target  
27 within that free space.

1           U.S. Patent No. 4,244,749 to Sachs et al.;  
2           U.S. Patent No. 4,681,264 to Johnson, Jr.  
3           U.S. Patent No. 5,035,363 to Somoza;  
4           U.S. Patent No. 5,209,221 to Reidlinger;  
5           U.S. Patent No. 5,681,396 to Madanshetty; and  
6           U.S. Patent No. 5,827,204 to Grandia et al.

7           Specifically, Sachs et al. discloses removal of  
8 biofouling from the external surfaces of spaced apart pipes of  
9 a heat exchanger which are in contact with a liquid by  
10 positioning a plurality of ultrasonic transducers between the  
11 pipes and operating the transducers at sufficient power levels  
12 to cause cavitation within the liquid to effect the desired  
13 cleaning action. The transducers are arranged in a planar  
14 configuration to produce bi-directional acoustic radiation.  
15 Various types of instrumentation are provided for determining  
16 the extent of biofouling and effectiveness of cleaning as well  
17 as for monitoring transducer operation parameters.

18          The patent to Johnson, Jr. discloses a process and  
19 apparatus for enhancing the erosive intensity of a high  
20 velocity liquid jet when the jet is impacted against a surface  
21 for cutting, cleaning, drilling or otherwise acting on the  
22 surface. A preferred method comprises the steps of forming a  
23 high velocity liquid jet, oscillating the velocity of the jet  
24 at a preferred Strouhal number, and impinging the pulsed jet  
25 against a solid surface to be eroded. Typically the liquid  
26 jet is pulsed by oscillating the velocity of the jet  
27 mechanically or by hydrodynamic and acoustic interactions.

1 The invention may be applied to enhance cavitation erosion in  
2 a cavitating liquid jet, or to modulate the velocity of a  
3 liquid jet exiting in a gas, causing it to form into discrete  
4 slugs, thereby producing an intermittent percussive effect.

5 Somoza discloses reducing the particle size of energetic  
6 explosive materials by slurrying the particulate explosive  
7 materials in an inert liquid such as water or an aqueous  
8 solution, and subjecting the slurry to intense acoustic  
9 cavitation from an ultrasonic generator for a short time. The  
10 particulate explosive materials are rapidly ground to a small  
11 particle size while minimizing the danger of detonation.

12 Riedlinger discloses a device for generating sonic signal  
13 forms for limiting, preventing or regressing the growth of  
14 pathological tissue that comprises an ultrasonic transmission  
15 system for transmitting sound waves, focused on the tissue to  
16 be treated, by way of a coupling medium. An ultrasonic signal  
17 produced at the focus of the system comprises brief pulses  
18 having at least one rarefaction phase with a negative sonic  
19 pressure amplitude with a value greater than  $2 \times 10^5$  Pa. The  
20 ultrasonic signal is radiated with a carrier frequency  
21 exceeding 20 kHz, a sonic pulse duration T of less than 100  $\mu$ s  
22 and a pulse recurrence rate of less than  $0/(5T)$ . The device  
23 produces controlled cavitation in the tissue to be treated.

24 The patent to Madanshetty discloses the surgical cleaning  
25 of a semiconductor wafer through the inducement of cavitation  
26 on the surface of the wafer at the location of an adherent  
27 particle. Cavitation is induced by focusing two acoustic

1 fields on the surface of the wafer. The two acoustic fields  
2 include a cavitation field having relatively low frequency  
3 focused on the wafer surface from a direction perpendicular to  
4 the wafer and a coaxing field of relatively high frequency  
5 focused on the wafer surface from a direction between 0 and 25  
6 degrees from the wafer surface.

7 Grandia et al. discloses medical noninvasive operations  
8 using focused modulated high power ultrasound that generally  
9 includes a transmitter for exciting a multifrequency  
10 ultrasound wave for causing vaporous cavitation bubbles in a  
11 small focal zone of a medical target region. Focused  
12 ultrasound can be used for both dissolving tissues as well as  
13 causing clots in order to destroy cancerous growths. The  
14 multifrequency wave includes an underlying low frequency  
15 signal for enabling optimal growth of microbubbles and at  
16 least one high frequency signal for enabling a narrow zone of  
17 focus of the ultrasound. A cavitation monitor may be provided  
18 for sensing a level of cavitation as well as providing  
19 feedback to the transmitter. In addition, an imaging system  
20 is provided for enabling viewing of the medical target area  
21 during the therapy.

22 It should be understood that the present invention would  
23 in fact enhance the functionality of the above patents by  
24 providing an array of intersecting acoustic beamforms in free  
25 water space, the acoustic beamforms being generated at a  
26 frequency and range to create a destructive cavitation field  
27 around an undesirable remote target.

1 SUMMARY OF THE INVENTION

2 Therefore it is an object of this invention to provide a  
3 self-defense weapon utilizing acoustic remote cavitation.

4 Another object of this invention is to provide an  
5 underwater self-defense weapon mounted on an underwater  
6 support vessel.

7 Still another object of this invention is to provide an  
8 acoustic remote cavitation weapon by generating an array of  
9 intersecting acoustic beamforms.

10 A still further object of the invention is to provide an  
11 acoustic remote cavitation weapon deriving power from an  
12 underwater support vessel and generating an array of  
13 intersecting acoustic beamforms at a long range.

14 Yet another object of this invention is to provide an  
15 acoustic remote cavitation self-defense weapon for generating  
16 a destructive cavitation in free water space.

17 In accordance with one aspect of this invention, there is  
18 provided a method of generating a predetermined field of  
19 cavitation around a remote target in an underwater  
20 environment. The method includes the steps of identifying a  
21 remote target location, generating at least two acoustic  
22 beamforms, each at a peak power output, from an underwater  
23 energy source, and controlling the generated acoustic  
24 beamforms to intersect with each other at the remote target  
25 location and thereby create a destructive cavitation field at  
26 the intersection of the beamforms.

1                   BRIEF DESCRIPTION OF THE DRAWINGS

2           The appended claims particularly point out and distinctly  
3 claim the subject matter of this invention. The various  
4 objects, advantages and novel features of this invention will  
5 be more fully apparent from a reading of the following  
6 detailed description in conjunction with the accompanying  
7 drawings in which like reference numerals refer to like parts,  
8 and in which:

9           FIG. 1 is perspective view of a self-defense weapon  
10 according to the present invention;

11           FIG. 2 is graph showing linear and non-linear absorption  
12 losses according to a preferred embodiment of the present  
13 invention; and

14           FIG. 3 is a graph showing acoustic power requirement  
15 versus range and depth according to a preferred embodiment of  
16 the present invention.

17

18                   DESCRIPTION OF THE PREFERRED EMBODIMENT

19           In general, the present invention is directed to an  
20 environmentally clean self-defense weapon, generally shown in  
21 operation in FIG. 1. The weapon 10 includes an array of  
22 selectively activated sonar devices 12, 14, 16, that will  
23 eliminate or destroy unwanted underwater objects 18 remotely  
24 without using explosive materials. It is a characteristic of  
25 the present invention that the underwater environment is that  
26 of free and open underwater space such as that found in lakes,  
27 oceans and other large bodies of water.

1       The underwater object 18 targeted for destruction is  
2 shown generically in FIG. 1 and may include mines, incoming  
3 torpedoes, marine fouling barnacles, and emergency rescue  
4 operations. It will be understood that the position of the  
5 underwater object 18 is not necessarily specifically  
6 identifiable, yet is within a range of about 100 meters to  
7 about 1 Km from a source vessel such as a submarine 20.

8       The weapon 10, including the array of sonar devices 12,  
9 14, 16, is mounted to or formed in connection with the  
10 submarine 20 or similar underwater vehicle capable of  
11 transporting and providing power to the weapon array 10. In  
12 the subject of FIG. 1, the weapon array 10, including three  
13 sonar devices 12, 14, 16, is shown to be targeting the object  
14 18 located a distance 22 from the submarine 20. The sonar  
15 sources 12, 14, 16 of the weapon 10 are mounted on the  
16 submarine 20 at predetermined intervals. For example, a first  
17 sonar source 12 may be mounted at the nose 30 of the submarine  
18 20, a second sonar source 14 mounted at a mid-section 32 of  
19 the submarine 20, and a third sonar source 16 mounted at a  
20 tail 34 of the submarine 20. This array spacing and number of  
21 sonar sources is by way of example only and will be modified  
22 to suit the particular underwater transport source.  
23 Regardless of the spacing of the array 10 or number of sonar  
24 sources used, the beams 12b, 14b, 16b from the sonar sources  
25 12, 14, and 16, respectively, will be directed to intersect at  
26 a cavitating focal point coinciding with the determined  
27 location of the target 18. The intersecting beams at the

1 cavitating focal point of the sonar sources will create a  
2 destructive cavitation field generally identified at 24 in  
3 FIG. 1.

4       The sonar sources 12, 14, and 16 of the weapon 10 are  
5 activated to generate a focused beam at a frequency of 10 KHz  
6 to 15KHz. All calculations for target 18 location, output  
7 frequencies, intersecting focal points of the sonar sources  
8 12, 14, 16, and required signals to control "firing" of the  
9 sonar sources is by way of an on-board computer 26 connected  
10 to the sonar sources.

11       Any general-purpose active sonar source can be used to  
12 assemble a weapon array 10 as in the present invention. The  
13 underlying physics is based on the intense heat and high-  
14 pressure pulse from the sonar sources 12, 14, and 16 as the  
15 damage mechanisms by virtue of the intense acoustic power of  
16 the sonar sources. An ensuing cavitation bubble formation and  
17 collapse and shock propagation will also inflict damages on  
18 underwater objects 18 targeted for removal. The technical  
19 drivers are the cavitation lethality on the undesirable  
20 objects 18 and the acoustic power of the sonar sources versus  
21 range and depth.

22       Any sonar array can be used in this mode. The stand off  
23 distance is the focal length of the array as defined by the  
24 intersection of the separate sonar sources 12, 14, 16. A  
25 function of physical dimension of the array is that the longer  
26 the span of the array along the support member 20, the farther  
27 away the standoff or target distance may be.



1       Historically, an acoustic array is always designed to  
2       avoid cavitation. This invention seeks to operate the  
3       acoustic array weapon 10 at its peak power output to maximize  
4       cavitation at the focal point of the array. The key elements  
5       of the operation are: computation of the focal point location  
6       and acoustic beamforming to cover the object location.

7       There are several advantages to the present invention  
8       including a lack of environmentally detrimental residues that  
9       will be generated. Further, beam forming greatly reduces  
10      response time so that more objects can be removed in a given  
11      time. Also, the present invention reduces cost per object  
12      removed. This concept also enables all sonar to be used as a  
13      device to remove undesirable objects. Furthermore, without  
14      any explosives and the increased standoff distance from the  
15      device, the operating platform of the underwater vessel 20  
16      with the sonar array 10 will not suffer any damage.

17      FIG. 2 is a graph illustrating linear and non-linear  
18      absorption losses over a temperature range of 0 to 13 degrees  
19      Celsius and a frequency of 1 to 30 KHz. FIG. 3 is a graph  
20      illustrating acoustic power requirement versus range and depth  
21      at 30 KHz.

22      The potential applications are numerous, and include  
23      without limitation thereto: mine neutralization; torpedo self-  
24      defense, melee close-in encounter; and any sources or  
25      communication systems that must be left behind.

26      In view of the above detailed description, it is  
27      anticipated that the invention herein will have far reaching

1 applications other than those of underwater destruction of  
2 undesirable objects.

3       This invention has been disclosed in terms of certain  
4 embodiments. It will be apparent that many modifications can  
5 be made to the disclosed apparatus without departing from the  
6 invention. Therefore, it is the intent of the appended claims  
7 to cover all such variations and modifications as come within  
8 the true spirit and scope of this invention.